Performance of Self-Adaptive Techniques for Multi-Static, Concurrent Detection, Classification and Localization of Targets in Shallow Water using Distributed Autonomous Sensor Networks

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LONG TERM GOALS

To develop multi-static synthetic aperture interferometry and iterative time-reveral technique, with little signal processing effort involved and a-priori information on the environment, to provide concurrent detection, classification and localization of proud and buried targets in shallow ocean waveguides.

OBJECTIVE

The proposed Georgia Institute of Technology (GIT) research effort will develop self-adaptive signal processing techniques to enhance the resonant acoustic signatures of man-made targets. These signal processing techniques will applied to the concurrent detection, classification and localization problem of these targets from an autonomous sensor network. Participation in the upcoming SWMASI'09 experiment, in collaboration MIT and MPL/SIO, will provide data to understand the fundamental performance and comparison between various sensor array configurations. The proposed research here will focus on the consistency and accuracy of the aforementioned self-adaptive methods when applied to scattered field data collected either on a vertical- receive array (VRA), or on a synthetic-aperture horizontal receive array (S-HRA) created from an AUV track, which is this the ultimate system implementation.

APPROACH

The GIT research effort, in collaboration with MIT and MPL/SIO, under the SWAMSI continuation, will address the fundamental scientific issues associated with using an autonomous underwater vehicle network for 3D multistatic concurent DCL of proud and buried targets by an autonomous underwater vehicle network. In particular the performance of the developed self-adaptive technique will be assesed for two main receive array configuration (VRA and S-HRA)

Modeling and Simulation

The benefit of multi-statics for DCL in littoral MCM is the ability to explore the bistatic enhancement inherently associated with targets designed to be stealthy in regard to monostatic sonar systems. The development and design of optimal search strategies is therefore strongly tied to the understanding of

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the 3D characteristics of the target scattering process, including the mutual interaction between the target and the seabed stratification.

Target Scattering, Propagation and Signal Processing

This research project will model the bistatic acoustic response of simple elastic objects (e.g. shell) in both free space and shallow water waveguide (usgin OASES coupled to a local finite-element modelling of the target).

Algorithm Development

The main issue is to separate out the environment from the structure of the target in a self adaptive method—that is, a method not requiring detail knowledge of the environment. Additionally, the frequency content of the various target resonances vary with the bistatic aspect. Hence a conventional beamforming approach are insufficient to enhance multi-static detection of the resonating targets. Instead we will investigate detection algorithm based on the full multi-static space-time-frequency response of elastic targets.

WORK COMPLETED AND PRELIMINARY RESULTS

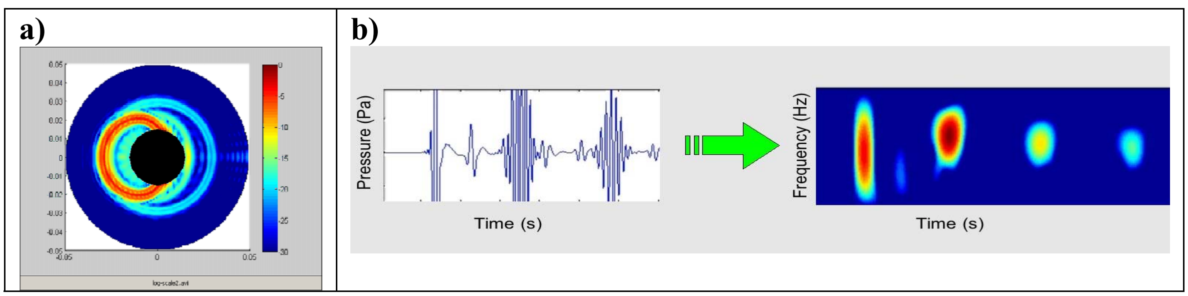

Figure 1: a) Bistatic response of an elastic shell (shell is 1m diameter, 1.5 cm thick steel). b) Time-frequency analysis of the backscatter response of an elastic stell (monostatic response). Note the various (narrowband) strong resonances appearing beyond the firstg specular echo.

For underwater sonar, time-frequency analysis and, in particular Wigner-Ville analysis, has been shown to be a relevant tool for discriminating a man made target (shell) from a natural one of the same shape (solid) and even to estimate some target characteristics (shell thickness, shear velocity..). This processing tool takes advantage of the evolutional, time dependent aspect of the echo spectrum (see Fig. 1). The estimated time-frequency patterns can be used for detection and wideband classification of sonar echoes in order to reduce false alarms. In particular, the so-called "coincidence pattern" appearing for specific frequency range is a robust time-frequency signature of man-made shells (see Fig. 2). Using a standard spherical shell model target model, a time-frequency analysis allows to understand echo formation mechanisms and their bistatic evolution (see Fig .3). The influence of the medium parameters as well as the source-receiver configuration was investigated in free space and will be extended to the case of a shallow water waveguide.

The influence of the medium parameters as well as the source-receiver configuration was also investigated in free space.

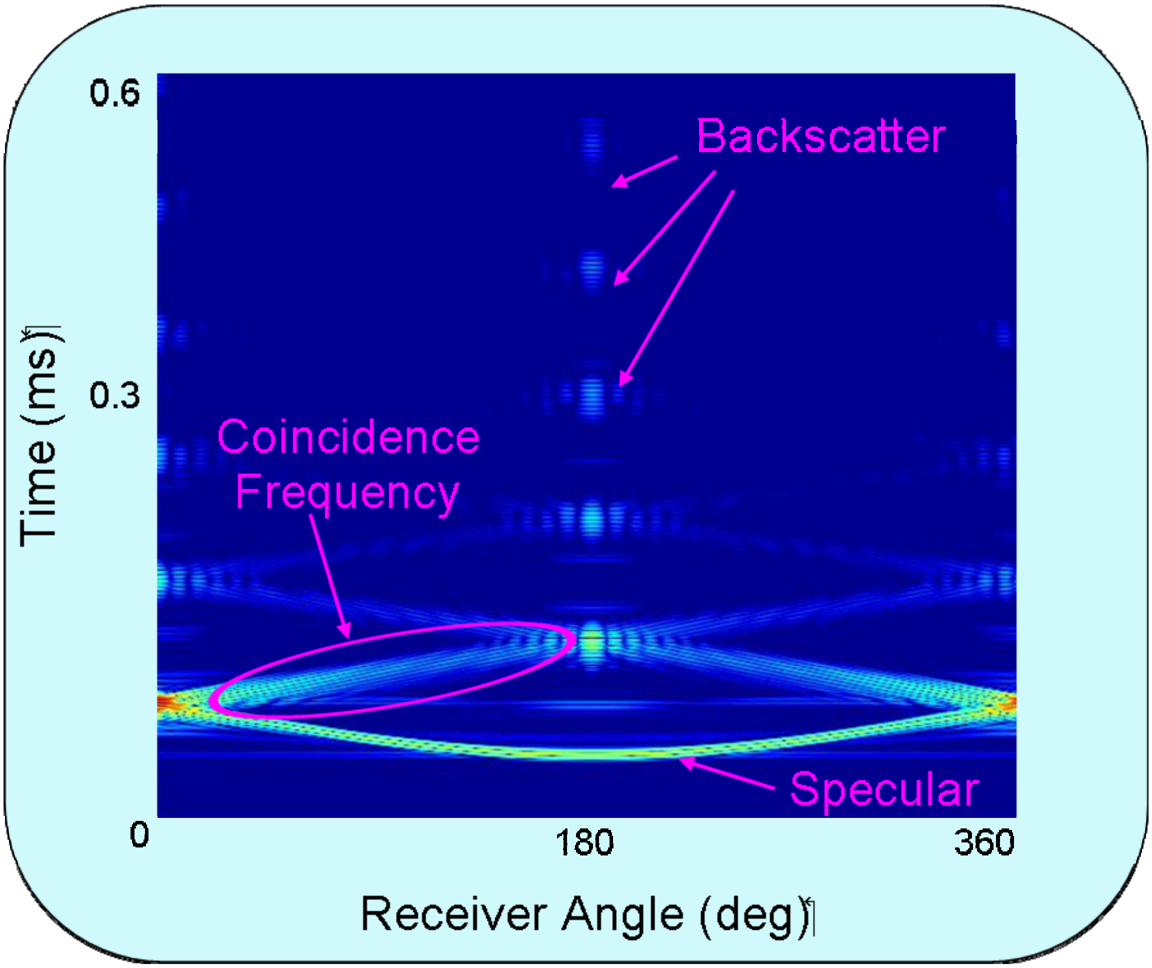

Figure 2: Sinogram of the same elastic shell (see Fig .1)

Most importantly the energetic coincidence pattern (resulting from the interactions of A0+ and A0- waves) appears to vary in the time-frequency plan when bi-static receiver angles changes.

This occur since the A0+ and A0- waves shift and separate as path lengths to the receiver vary for bi-static receiver angles (see Fig. 3). Hence a coherent processing of the various echoes of the spherical shell will not be possible using conventional approach limited to the frequency domain (e.g. conventional beamforming) since the frequency content of the echoes is not constant. Instead the full space-time-frequency coherence of the echoes need to be combined to enhance detection with respect to surrounding ambient noise and reverberation due to clutter.

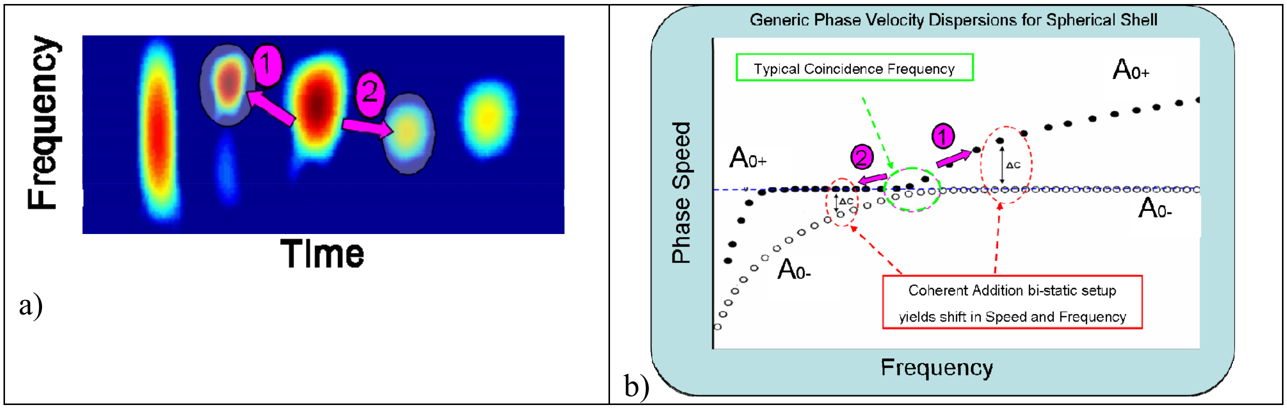

Figure 3: Splitting of the bistatic time-frequency signature of the elastic shell in two patterns (#1 and #2) corresponding to the two coherent interference of A0+ and A0- waves when their path lengths around the sphere vary (bistatic configuration); b) Theoretical interpretation of the observed time-frequency shift of the coincidence pattern due to variations in path length which is compensated by the difference in phase velocity of the interfering A0+ and A0- waves away from the coincidence pattern.

IMPACT

This work is focused on developing potential MCM procedures to improve multistatic concurrent Detection, Classification and Localization of elastic target by investigating the full space-time-frequency coherence of their echoes.

PUBLICATIONS

"Time-frequency analysis of the bistatic response of elastic shells", S. Anderson, K. G. Sabra. Paper in preparation.